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Comparative Analysis of Desalination Technologies

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Abstract

As the world population is growing, the need for fresh water is increasing. Water desalination is a mean for producing fresh water from saline water abundant in seas and oceans. Various technologies have been used to desalinate saline water with different performance characteristics. This work outlines current desalination technologies and compares their performance in terms of input and output water quality, amount of energy required, environmental impact and cost. It was found that adsorption desalination technology is a promising method for desalinating seawater due to its low running cost and low environmental impact as it uses waste energy resources.

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Keywords: Desalination; Thermal; Membrane; Chemical; Adsorption.

1. Introduction

World water resources are mainly salty (97.5%) and fresh water (2.5%). Salty water is found in oceans, seas and some lakes while fresh water is either stored underground (30%) or in the form of ice / snow covering mountainous regions, Antarctic and Arctic (70%) but only 0.3% is usable by humans [1]. With this limited amount of usable fresh water, desalination offers the means to meet the increasing demand for fresh water. Desalination technologies are divided into three major groups, namely: (i) thermally-activated systems in which evaporation and condensation are the main processes used to separate salts from water, (ii) pressure-activated systems where a pressure is applied on the salty water that forces it through a membrane, leaving salts behind and (iii) chemically-activated desalination methods. Thermally activated systems include: multi-stage flash distillation (MSF), multiple-effect distillation (MED), vapor compression distillation (MVC), humidification - dehumidification desalination (HDH), solar distillation (SD) and freezing (Frz). In these systems, heat transfer is used either to boil or freeze the seawater or brackish water to convert it to vapor or ice so the salts are separated from the water. Pressure- activated systems use permeable membranes to create two zones where water can pass through leaving salt behind.

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These technologies consist of reverse osmosis (RO), forward osmosis (FO), electro-dyalysis (ED) and nanofiltration (NF). Chemically-activated desalination systems include ion-exchange desalination (I.Ex), liquid–liquid extraction (LLE) and gas hydrate (G.Hyd) or other precipitation schemes [1, 2]. Recently, adsorption technology (Ads) has been investigated for desalination application. In this technology an adsorbent material with high affinity to water like silica gel can be used to separate the water from the salts [1]. Figure 1 shows flow chart of the various desalination technologies [1, 2]. This work aims to critically assess the performance of all available desalination systems in terms of energy required, cost, quality of feed and produced fresh water and environmental impact.

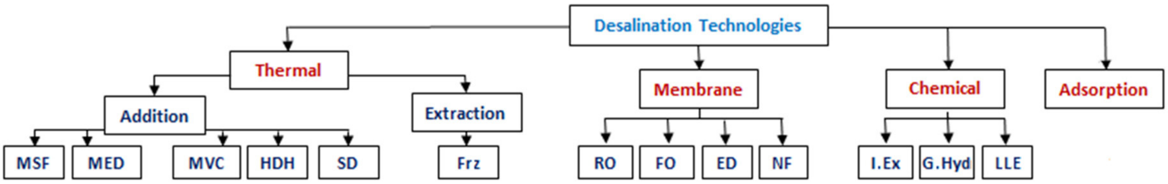

Fig. 1. Classification of desalination technologies

2. Results

Several parameters affect the selection of desalination systems including; quality of salty water to be desalinated, salinity level of produced potable water, input energy, environmental impact and cost. According to salinity of water, it could be categorized into brackish or seawater. Brackish water contains total dissolved solids (TDS) higher than potable water and lower than seawater. Potable water should have TDS lower than 1000 ppm (or mg/l) and brackish water in the range of 1,000 to 25,000 ppm while seawater has an average of 35,000 ppm TDS concentration [2]. Figure 2 shows the variation of feed water and produced water salinity for the listed technologies. It is clear from this figure that MSF and Ads desalination technologies can handle feed water with the highest salinity and produce water with the lowest salinity. Figure 3 shows the amount of thermal and/or electrical energy required by each technology. It is clear from this figure that SD, I.Ex, G.Hyd and Ads require the least amount of energy (below 2kW.hr/m^3). Figure 4 shows the environmental impact of each technology in terms of the amount of CO_2 emissions, where all the calculations were based on; emission factor for burning of natural gas of $6.42x10^{-5}$ tCO_2/MJ (thermal energy) and on CO_2 emission factor for electricity generation of 0.4612 tCO_2/MWh [1]. It is clear from this figure that SD, I.Ex, Ads and G.Hyd produce the least amount of CO_2 below 0.7 kg/m^3. Figure 5 shows the running cost of the listed technologies where Ads, Frz and LLE have the lowest cost of below 0.5\$/m^3.

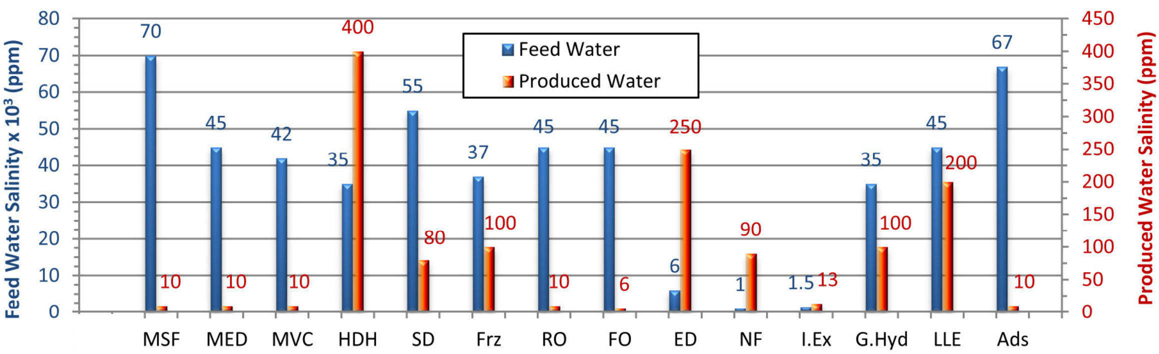

Fig. 2. Different Desalination Systems Capabilities Regarding Salinity of Feed and Produced Water measured in ppm, [1-21].

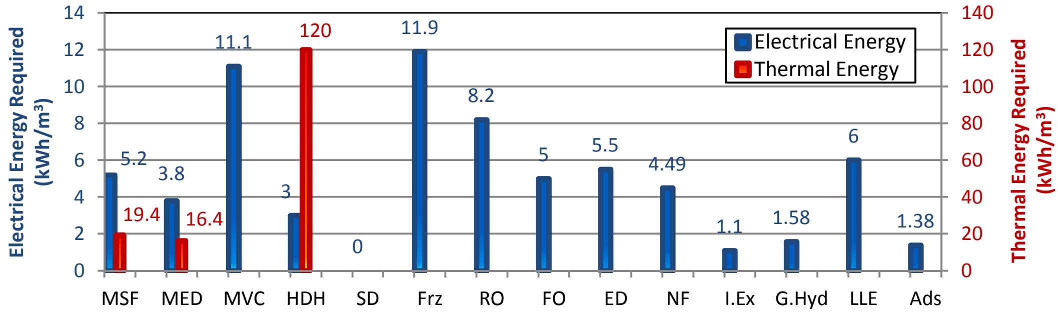

Fig. 3. Amount of energy required for different desalination technologies, [1, 21- 28].

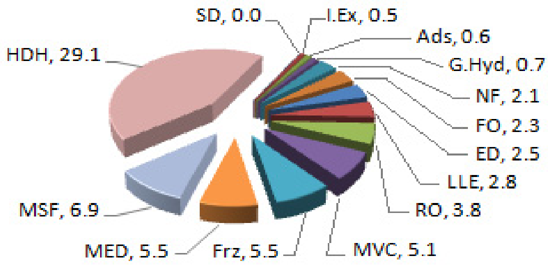

Fig. 4. Amount of Released CO_2 for different desalination technologies measured in kg/m^3

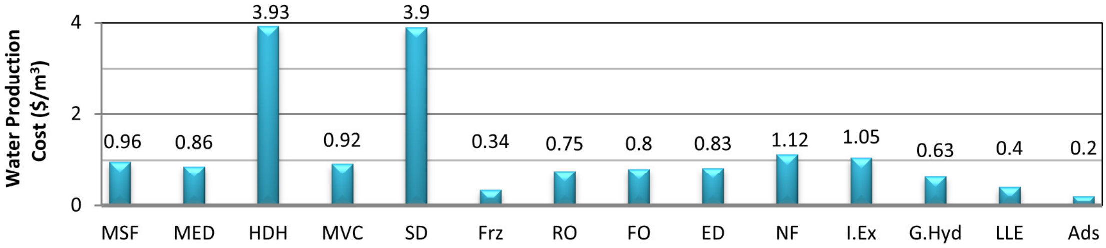

Fig. 5. Potable water production cost for different desalination technologies, [1, 23, 29-31].

3. Conclusions

Desalination technology is increasingly becoming important to meet the increasing worldwide water demand. Various technologies are available but they suffer from various drawbacks like large power input and high CO_2 emissions. This work critically assessed the currently available technologies and concluded that adsorption based desalination technology can handle feed water with high salinity (up to 67,000ppm) and produce low salinity water (10ppm) with minimum running cost (0.2$/$m^3$) and low environmental impact (0.6kg/m^3).

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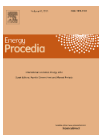

Biography

Peter Youssef graduated from Alexandria University, Egypt in 2011 with MSc degree in Thermal engineering. Currently he is a PhD researcher in the field of adsorption technology for desalination applications.